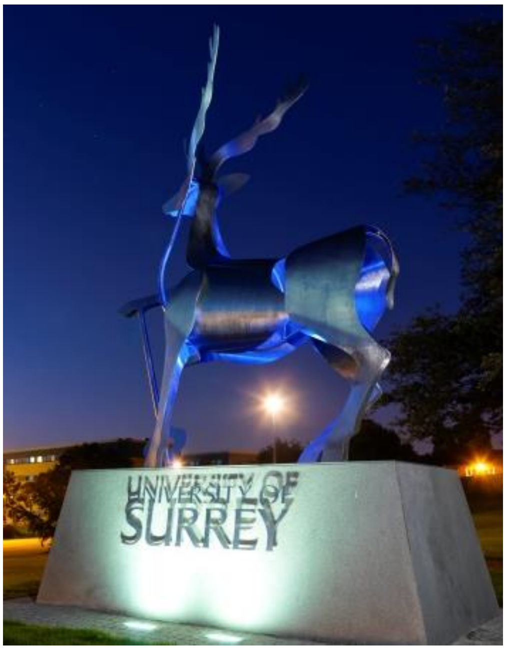
UNIVERSITY OF SURREY

INTERNATIONAL WORKSHOP ON FUTURE LIGHT TECHNOLOGY AND HUMAN HEALTH

Programme and abstract booklet

21 – 22 September 2015

University of Surrey, Guildford, UK



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UNESCO
United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

Welcome and programme:

FUTURE LIGHT TECHNOLOGY AND HUMAN HEALTH

Light has always played a critical role in the lives of humans. From the role natural light plays in nature and its effect on humans to the discovery and development of artificial light sources. The last decades have shown great progress in the understanding of the non-visual response to light and also great technological innovation through the development of the white LED. The latter being made possible by the work on the gallium nitride based blue LED, the inventors of which won the Nobel Prize for Physics in 2014.

This unique international workshop aims to bring together researchers from the areas of photonic device physics and engineering, lighting technology and design, circadian and sleep research, physiology and psychobiology to discuss the current state-of-the-art research challenges in lighting design in general and also more specifically in terms of the effect of artificial light on human health and performance.

UNESCO has declared 2015 as the International Year of Light (http://www.light2015.org). One of its core objectives is to "promote Light-based Technologies directly responding to the needs of humankind".

Thus, this workshop is a timely opportunity, recognising the role light plays in society, to learn from academia, industry and government stakeholders, facilitating a better understanding of the properties of modern lighting required for health but also how challenges and opportunities in lighting design for varied applications can be met through interdisciplinary research.

We wish you an enjoyable and productive workshop.

Organising committee

Dr Konstanze Hild, Advanced Technology Institute, University of Surrey
Prof Stephen J. Sweeney, Department of Physics, University of Surrey
Prof Debra J. Skene, Department of Biochemistry and Physiology, University of Surrey
Dr Vikki L. Revell, Surrey Clinical Research Centre, University of Surrey

Welcome and programme:

WORKSHOP PROGRAMME

Monday 21 September (Venue: Treetops, Wates House)

12:30	**Buffet lunch and registration**		
13:30	**Welcome and Introductions:** K. Hild, S.J. Sweeney, D.J. Skene, University of Surrey		
Session 1: Setting the scene			
14:00	*LED science and technology for solid-state lighting*	Colin Humphreys	University of Cambridge
14:40	*The neurophysiology of non-visual responses to light*	Rob Lucas	University of Manchester
15:20	*Developing Standards of Performance for Lighting across the European Union*	Mike Walker	Department for Energy and Climate Change
15:40	**Tea break**		
Session 2: Light and Health			
16:10	*Lighting and Health Light and health: Practical measurement advice*	Luke Price	Public Health England
16:30	*Insights on needs for light for mental wellbeing*	Marjolein van der Zwaag	Philips Research Eindhoven
16:50-17:10	*Pupillometry as a tool for light evaluation*	M. Angeles Bonmatí-Carrión	University of Murcia
18:30	**Workshop Dinner (Weyside, Guildford)**		

Tuesday 22nd September (Venue: Treetops, Wates House)

Session 3: Technological approaches			
9:00	*Semipolar InGaN LEDs with long emission wavelengths and high efficiency*	Tao Wang	University of Sheffield
9:40	*Light from plastics: Organic Light Emitting Diodes*	Chris Mills	Tata Steel R&D
10:00	*Photonic crystal structures for enhancement of light extraction from LEDs*	Zoe Bushell	University of Surrey
10:20	**Coffee Break**		
Session 4: Light and Life			
10:50	*Why Humans need Light*	Anna Wirz-Justice	Psychiatric University Clinics Basel
11:30	*The challenges of delivering technology for circadian lighting*	James McKenzie	Photonstar LED Ltd.
11:50	*Towards a circadian-friendly lighting: effects on a diurnal and a nocturnal animal model*	M. Angeles Bonmatí-Carrión	University of Murcia
12:10	**Lunch**		

Welcome and programme:

Session 5: Technology, applications and standards			
13:10	*Driving innovations in light: research and user insights for Human Centric Lighting applications*	Luc Schlangen	Philips Lighting
13:50	*Micro-LED probes for optogenetic control of neural circuits*	Keith Mathieson	University of Strathclyde
14:10	*Defect reduction in the Overgrown (11-22) GaN Layer on Regularly Arrayed Microrod Templates*	Yun Zhang	University of Sheffield
14:30	*Lighting Standards for Solid-State Lighting*	Simon Hall	National Physical Laboratory
15:10	**Tea and Discussion**		
16:10	**Workshop Close**		

Session 1: 14:00 – 15: 40 Setting the Scene

14:00

LED Science and Technology for solid-state lighting

Colin Humphreys
Professor and Director of Research, The Cambridge Centre for Gallium Nitride (GaN), Department of Materials Science and Metallurgy, University of Cambridge,27 Charles Babbage Road, Cambridge CB3 0FS, UK

14:40

The neurophysiology of non-visual responses to light

Rob Lucas
Professor of Neurobiology, Faculty of Life Sciences, AV Hill Building, Oxford Road, Manchester, M13 9PT, UK

Light has wide ranging effects on human physiology and behaviour. I will provide an overview of how the neurophysiological signal producing these effects is generated in the retina using a combination of the well-known rod and cone photoreceptors and a more recently discovered dedicated photoreceptive mechanism. I will provide a particular emphasis on how this arrangement impacts the spectral sensitivity of these non-visual responses and implications for the most appropriate ways of measuring and applying light.

15:20

Developing Standards of Performance for Lighting across the European Union

Mike Walker
Head of Sustainable Energy-using Products, Department of Energy and Climate Change, 3 Whitehall Place, London, SW1A 2AW, UK

Across the globe, the energy consumption (or energy efficiency) of an increasing number of products, including lighting products, is subject to national or regional limits. In the European Union, minimum standards of performance are set by product specific regulations made under the Ecodesign Directive; in addition, energy labels, used to indicate to consumers the most efficient products, are made under the Energy Labelling Directive. The process for agreeing standards typically takes around 4 years per product, and entails extensive consultation with stakeholders from industry, consumers and Non-governmental Organisations.

Since 2009, minimum performance standards and energy labels have been agreed for lighting used in homes, business premises and street lighting. Standards have been set for lighting products that can be placed on the EU market that address, for example

Energy efficiency (lumens per watt)
Colour temperature
Beam

The paper will discuss the process by which standards are made, identifying the opportunities for interested parties to provide inputs and representations.

Session 2: 16:10 – 17:10: Light and Health

16:10

Light and health: Practical measurement advice

Luke Price
Senior Radiation and Protection Scientist, Public Health England, Chilton, Oxfordshire, UK

Accurately measuring optical radiation in health studies is important, and the presentation will summarise some of the key challenges facing researchers, and known solutions. Focusing on the effects of light on circadian rhythms, some of the basics of photobiological measurements are recapped. A suggested strategy for improving study quality and reproducibility emerges, by creating a robust dosimetry chain including calibration, standards and metrics. Finally, concerns about the "Blue Light Hazard" are addressed with some recent measurements of modern light-emitting devices.

16:30

Insights on needs for light for mental wellbeing

Marjolein van der Zwaag
Research Scientist in the Brain, Cognition & Perception group of Philips Research Eindhoven, The Netherlands

An increasing amount of evidence is building up on the positive impact of light on our biological and psychological wellbeing. The biological effect includes the effect of light on our circadian rhythm and mood. The psychological effect includes the impact that colored light has on trusting people, atmosphere creation, and next to that control of light can give people the feeling of empowerment and personalization.

Biological treatments with light are frequently given via most often done via bright light therapy lamps. These lamps, however, tend to be bulky and have a medical look which might reduce adherence to the treatment. The challenge with the psychological benefits of light is that they are still unfamiliar to many people.

We have started to acquire user needs of light therapy lamps via people-centric design and user experience research. These initial needs were translated into design guidelines on how light therapy lamps might be improved to increase adherence. Also, potential ways of how light can be applied to generate psychological benefits have been explored. This presentation gives an overview of our results on both aspects for mental wellbeing.

16:50

Pupillometry as a tool for light evaluation

M. A. Bonmatí-Carrión[1], K. Hild[2], C. Isherwood[3], B. Middleton[3], S.J. Sweeney[2], V.L. Revell[3], J.A. Madrid[1], M. A. Rol[1] and D. J. Skene[3]

[1]*Chronobiology, Faculty of Biology, University of Murcia, 30100 Murcia, Spain*

[2]*Advanced Technology Institute, University of Surrey, Guildford, GU2 7XH, UK*

[3]*Chronobiology, Faculty of Health and Medical Sciences, University of Surrey, Guildford, GU2 7XH, UK*

The pupillary light reflex (PLR) is driven by the rods, cones, and intrinsically photonsensitive retinal ganglion cells (ipRGC) which express the photopigment melanopsin (Berson, 2003). These ipRGCs innervate both the circadian system central pacemaker (the suprachiasmatic nulei, SCN), and the regulatory centre for the pupillary light reflex (the olivary pretectal nucleus, OPN) (Berson, 2003). Thus they constitute a key link between circadian light inputs and pupillary light reflex, thus they can be used to rapidly evaluate the effect of different lights on the circadian input pathways. Consequently, pupillometry could be used to evaluate the efficiency of light sources on circadian system activation in a quick, non-invasive and inexpensive way. However, to date the PLR has not been fully characterized spectrally in a large cohort of participants at very narrow bandwidth increments. Our aims were: i) to compare 5-min short (λmax 437 nm and 479 nm) and long (λmax 627 nm) wavelength light (alone and in combination) at two irradiances on the PLR (study A, n=13); ii) assess spectral sensitivity of the PLR to monochromatic light in the λmax 420-500 nm range (study B, n=16), nine stimuli in 10-nm increments. The minimum pupil diameter and the area under the curve (AUC) during the first minute (0-60s) and last minute of light exposure (240-300s) were assessed. The isolated photoreceptor contribution was estimated by mathematical modeling (Irradiance toolbox (Lucas et al., 2014)).
In Study A, the minimum diameter was smallest under blue light and the lowest AUC0-60 (greater contraction) was found under "479+627" nm light. An irradiance dependency was observed for 437 nm and 479 nm light. In Study B, the lowest minimum diameter was achieved under 470 nm light, with the lowest AUC0-60 and AUC240-300, under λmax 490 nm and 460 nm, respectively. Our data agree with Mure et al. (2009) and suggest that the sustained response is most sensitive to 460 nm light.

References

Berson, D. M. Strange vision: Ganglion cells as circadian photoreceptors. Trends Neurosci.2003, 26, 314–320.

Lucas, R. J.; Peirson, S. N.; Berson, D. M.; Brown, T. M.; Cooper, H. M.; Czeisler, C. A.; Figueiro, M. G.; Gamlin, P. D.; Lockley, S. W.; O'Hagan, J. B.; Price, L. L. A.; Provencio, I.; Skene, D. J.; Brainard, G. C. Measuring and using light in the melanopsin age. Trends Neurosci. 2014, 37, 1–9.

Mure, L. S.; Cornut, P.-L.; Rieux, C.; Drouyer, E.; Denis, P.; Gronfier, C.; Cooper, H. M. Melanopsin bistability: a fly's eye technology in the human retina. PLoS One 2009, 4, e5991.

Session 3: 09:00-10:50: Technological approaches

09:00

Semipolar InGaN LEDs with long emission wavelengths and high efficiency

Tao Wang
Professor of Advanced Optoelectronics, Department of Electronic and Electrical Engineering, University of Sheffield, Mappin Street, S1 3JD, UK

The most successful example of large lattice-mismatched epitaxial growth of semiconductors is the growth of III-nitrides on sapphire, leading to three Nobel Prize Laureates in 2014. However, the major developments in the field of III-nitrides is mainly limited to polar GaN grown on c-plane sapphire. So far, the growth of c-plane GaN on sapphire has almost approached its theoretical limits. Furthermore, this polar orientation poses a number of fundamental issues, such as reduced quantum efficiency, efficiency droop, green & yellow gaps in wavelength coverage, etc. It is worth highlighting that green/yellow emitters play crucial roles in not only solid state lighting but also healthcare (such as optogenetics). One clear way forward, meeting all the fundamental challenges, would be to grow GaN along semi-polar directions, in particular, (11-22) orientation. This semipolar orientation can also significantly enhance indium incorporation into GaN, which cannot be achieved using c-plane GaN and thus is extremely important for growth of long wavelength emitters, such as green/yellow LEDs. Unfortunately, the crystal quality of semi-polar GaN directly grown on sapphire is far from satisfactory. As a result semi-polar GaN based emitters with device performance have to be grown on semi-polar GaN substrates, obtained only by slicing very thick c-plane GaN along semi-polar orientations, limiting to a size of 10´10 mm2. This is extremely expensive, and thus impractical. The Sheffield team has developed a number of overgrowth approaches for (11-22) semi-polar GaN on sapphire with significantly enhanced crystal quality, which is even better than that of standard c-plane GaN on sapphire. InGaN based LEDs with a wide range of emission wavelengths of up to 610 nm (amber) have been grown on such high quality semipolar GaN, demonstrating significantly high optical performance. For example, our yellow LEDs (583 nm) exhibit an internal quantum efficiency (IQE) of ~10%, significantly reduced efficiency droop, and significantly reduced blue-shift induced as a result of increasing injection current. Those results cannot be achieved by growth on c-plane GaN. In addition, detailed mechanisms for defect reduction of our semipolar GaN will be provided, and optical investigation of the semipolar InGaN LEDs will be presented as well.

09:40

Light from plastics: Organic Light Emitting Diodes

Chris Mills
Senior researcher, Advanced Coatings Group, Tata Steel R&D, and visiting researcher, Advanced Technology Institute, Guildford, UK

Major advances have recently been achieved in lighting and display technologies. More efficient, and hence lower cost, lighting has been achieved through a progression away from conventional filament-based light bulbs to semiconducting, light emitting diodes (LEDs) and compact fluorescent lamps. In display technology, a subsequent development of LED televisions has improved picture quality and reduced energy consumption. However, whereas the current LED technology is primarily based on inorganic materials, such as gallium phosphide (red), gallium nitride (green) and zinc selenide (blue), the next generation of LED technology may be built on plastics that can emit light.

These plastics, called semiconducting polymers, can be used to produce energy efficient “organic” light emitting diodes (OLEDs), which do not incorporate the rare metals found in many current LEDs, but which retain the inherent properties of plastics, such as flexibility, and produce light intensities equivalent to conventional light sources. The ability to chemically "tune" the properties of semiconducting polymer, or to blend or stack more than one polymer, allows the spectral composition of the light to be altered as required, and the inherent solution processability of the polymers gives rise to the possibility of printable lighting and displays.

Here, a review of OLED production and performance will be given, highlighting the advantages of the technology and pinpointing the technological hurdles to be overcome for future wide-scale applicability. A summary of the possible applications of the technology will be discussed, for lighting and displays in general and health applications in particular.

10:00

Photonic crystal structures for enhancement of light extraction from LEDs

Z.L. Bushell, M. Florescu and S.J. Sweeney
Advanced Technology Institute & Department of Physics, University of Surrey, Guildford, GU2 7XH, UK

Light emitting diodes (LEDs) are able to generate light with a high internal efficiency but typically suffer from poor external efficiency. This is due to a large fraction of the generated light being trapped in the semiconductor by total internal reflection and thus not contributing to the emission. Various approaches are used to improve light extraction efficiency, such as surface roughening, patterned substrates and photon recycling. Another possible method is to incorporate photonic crystal structures into the LED.

Photonic crystals are structures with a periodic variation of the refractive index on the order of the wavelength of light. This leads to the formation of a band structure for light propagating within the photonic crystal. Through the design of suitable structures, the properties can be tailored to control the propagation and scattering of light. In the case of LEDs, the use of photonic crystal regions can enhance the extraction of light by deliberately inducing scattering from the semiconductor to air.

Session 4: 10:50 – 12:10: Light and Life

10:50

Why humans need light

Anna Wirz-Justice
Professor of Psychiatric Neurobiology, Centre for Chronobiology, Psychiatric University Clinics Basel, Switzerland

The most obvious function of light to the eye is sight. We also know how important skin exposure is for adequate Vitamin D. The rapid and fascinating development in recognising non-visual aspects of light via the eye has added a broad spectrum of functions that, added together, suggest a crucial role for light in health. Classic laboratory studies showed that light suppresses synthesis of the pineal hormone melatonin, and induces time-dependent phase shifts of circadian rhythms. Detailed investigation of the intensity/duration/wavelength response has provided the scientific background for discussing light design. However, real life is a bit more complicated and less controlled: response is modified by interindividual differences (such as sex, age, clock gene polymorphisms), photic history and day-to-day light oriented behaviour. The latter can be documented with a lux-meter often combined with an activity monitor: such field data will provide a basis for lighting designed to complement outdoor exposure. It is noteworthy that the effect of light on mood, sleep and cognition was first utilised as light therapy for seasonal affective disorder (then for depression in general), later extended to treating circadian rhythm sleep disorders, and most recently, to stabilise emotions and sleep in patients with dementia. There is a huge potential for lighting strategies enhancing quality of life in health and disease.

11:30

The challenges of delivering technology for circadian lighting

James McKenzie and Fenella Frost
Photonstar LED Ltd., Belbins Business Park, Romsey, SO51 7JF, UK

PhotonStar have been developing and installing circadian lighting systems since 2008. This paper will discuss the challenges of two aspects of delivering the technology for circadian lighting.

The first part looks at the challenges in delivering a dynamic light source that is optimised for non visual needs, and considers how this may be achieved whilst meeting all of the performance and longevity requirements of the established visual lighting standards.

The second part reviews progress in the necessary control technology, with a focus on more recent developments in wireless and IoT as part of a more viable solution. A more in depth analysis of the recent work funded by the Department of Energy and Climate change, with the support of IBM and ARM will be presented. This work addressed the barriers to adoption due to cost and practicality of installing the technology in existing buildings. It also looks at how the emerging internet of things is permitting a big picture approach where the control of natural and electric light can be controlled together in an intelligent way, with working examples. Delegates will be challenged on how systems might need to change in future as our understanding of our non visual systems grows.

The presentation concludes with a case study of a system in use at a mental health facility in the UK.

11:50

Towards a circadian-friendly lighting: results in diurnal and nocturnal animal models

M. A. Bonmatí-Carrión, B. Bano-Otálora, M.A. Rol and J.A. Madrid
Chronobiology, Faculty of Biology, University of Murcia, 30100 Murcia, Spain

The circadian system, driven in mammals by a circadian pacemaker, the suprachiasmatic nuclei (SCN) of the hypothalamus, allows organisms to adjust their physiology by anticipating daily environmental changes. The light/dark cycle daily reset the activity of the SCN to maintain a stable phase-relationship with the environment. However, nights in developed countries are excessively illuminated. This light at night can cause chronodisruption, a circadian system disorganization that has been associated with different disorders. Not only light intensity and timing, but also the spectrum must be considered to keep SCN properly entrained, since blue light seems to be the most disruptive at night. Here, we evaluate the capacity of the diurnal Octodon degus and nocturnal Rattus norvegicus to synchronise to different nocturnal lights spectra. A total of 27 degus and 12 male Sprague Dawley rats were individually housed and exposed during the daytime (12h) to an illumination consisting of combined Red-Green-Blue LEDs (RGB). At night (12h), different conditions were applied: i) Darkness; ii) Red light; iii) combined Red-Green LED (RG) lights; and iv) combined Red-Green-Violet LED (RGV) lights. Their wheel running activity (WRA) patterns were evaluated under each light condition. Finally, they were maintained in darkness before receiving a 1-h light pulse of RGB and RGV at CT16, quantifying WRA, plasma melatonin and c-Fos expression in the SCN. Degus remained synchronized maintaining their WRA diurnal pattern under all light conditions tested, while rats free-run when green light at night was introduced (RGB:RG) and became arrhythmic under RGV. In both species, SCN c-Fos activation tended to be higher following the RGB-light pulse compared to RGV-pulse. This study shows the effectiveness of a nocturnal light obtained by replacing blue for shorter wavelengths to maintain circadian entrainment specifically in a diurnal rodent. This could be of importance to design lighting systems that reduce the disruptive effects of light at night in humans without compromising chromaticity.

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Session 5: 13:10 – 16:10: Technology, applications and standards

13:10

Driving innovations in light: research and user insights for Human Centric Lighting applications

Luc Schlangen
Principal Scientist in the Brain, Cognition & Perception group of Philips Research Eindhoven, The Netherlands

Light is a powerful stimulus that enhances people's lives in many ways. Light can dazzle, delight, inspire, inform and entertain. Light also powerfully regulates our body clock and our sleep-wake cycle. It can ameliorate sleep, increase concentration, treat depression, and improve weight gain of preterm infants. Moreover, light can reduce stress, pain medication usage and delirium incidence. The strong influence of light on human well-being, performance and health is a major innovation driver for novel Human Centric Lighting applications in which visual and non-visual effects of light are combined. The presentation will highlight how user insights, application needs, and scientific insights are combined to realize innovative lighting systems that carry beyond illumination. Also the impact of standardization, energy efficiency and digitalization within this process will be discussed. During the presentation several lighting applications and practical examples will be touched upon; from lighting for offices, cities, classrooms, elderly care, hospital patient rooms to personal light devices.

13:50

Micro-LED probes for optogenetic control of neural circuits

R.P. Scharf [1], T. Tsunematsu [2], S. Sakata [2], D. Zhu [3,4], E. Gu [1], I.M. Watson [1], D.J. Wallis [3,4], C.J. Humphreys [3], M.D. Dawson [1] and **Keith Mathieson** [1]

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[4] *Plessey Semiconductors Ltd, Plymouth PL6 7BQ, UK*

Optogenetics is a technique that permits optical control over genetically targeted neurons. It is allowing neuroscientists to probe neural circuits with unprecedented selectivity and helping to elucidate mechanisms behind neurodegenerative diseases. In order to realise the full potential of this technique, optical technologies, capable of delivering light in spatio-temporal patterns to deep regions within the *in vivo* brain, are needed.

Here we show a new device for light delivery at depth using micro-LED neural probes. We have developed and fabricated a needle-shaped device for cortical insertion, which consists of sixteen 25 µm-diameter LEDs linearly-spaced over 750 µm allowing precise spatial activation of neurons. The work was performed with high-performance GaN LED epistructures grown on 150-mm silicon substrates and emitting at wavelengths of ~450 nm. The good mechanical and thermal properties make a very compact design possible (100 µm × 30 µm × 3 mm), minimising tissue damage.

The in-vivo experiments were conducted in a genetic strain of mice expressing the blue-sensitive excitatory opsin, Channel Rhodopsin-2 (ChR2) Our microLED probe has been paired with a 32-channel linear recording electrode probe and neuronal action potentials have been evoked with site specific accuracy. The fabrication process is scalable to hundreds of sites, making it a useful neuroscience tool for brain research.

14:10

Defect reduction in the Overgrown (11-22) GaN Layer on Regularly Arrayed Microrod Templates

Y. Zhang, J. Bai. R. M. Smith. Y. Hou, Y. Gong, and T. Wang
Department of Electronic and Electrical Engineering, University of Sheffield, Mappin Street, S1 3JD, UK

Semipolar (11-22) InGaN/GaN LED structures have received much attention in recent years due to their potential to produce high efficiency LEDs in the green-yellow spectral range and overcome the so called 'green gap'. Allowing the realization of high efficiency RGB and RGYB LED lighting that would enable the dynamic control of colour composition. However, due to the lack of suitable substrates, semipolar GaN heteroepitaxial films usually contain high densities of defects, including basal stacking faults (BSFs) and related partial dislocations (PDs). These high densities of extended defects deteriorate the optical properties of quantum wells grown on the GaN films, leading to poor device efficiency. Recently, our group have developed a cost-effective microrod template overgrowth approach, producing high crystal quality films on sapphire substrates. Using this technique, a range of high internal quantum efficiency semipolar (11-22) InGaN/GaN MQWs were grown, with emission wavelengths from green to amber. This demonstrates the impressive ability of the microrod overgrowth process to block the dislocations and BSFs in semipolar GaN films. Developing an understanding of the mechanism of defect reduction during the overgrowth is key to further improvements of the crystalline quality and related device performance.

Here, we report the defect reduction in the semipolar (11-22) GaN layers overgrown on regularly arrayed microrod templates. From the transmission electron microscopy (TEM) measurements, it is discovered that the majority of the threading dislocations are blocked both by the SiO2 layer, lateral growth and the coalescence during the overgrowth. Owing to the faster growth rate along the +c direction than the a direction, a significant proportion of the BSFs are impeded during the overgrowth process. In addition, the BSFs are found to expand within the basal plane with components parallel to the m direction. This leads the BSFs on the surface to follow a distribution of spaced stripes consisting of small BSF clusters in between low defect density material, which is also confirmed by confocal PL mapping measurements.

14:30

Lighting Standards for Solid-State Lighting

Simon Hall
Lead Scientist for Adaptive Optics, National Physical Laboratory, Teddington TW11 0LW, UK

Artificial lighting fulfils a key societal need to decouple human activities from the variability of natural light sources. Lighting represents approximately 8% of global greenhouse gas emissions and 19% of global energy consumption, which costs global end-users a grand total of $234 billion each year. Solid state lighting (SSL) is about five times more efficient than conventional lighting – typically producing 100 lumens per watt compared to 20 lm per W for halogen bulbs. It produces instant white light allowing good colour perception but it also offers functionality that enables smarter lighting solutions, requires less maintenance and has longer lifetimes. SSL lighting has the potential to reduce electricity consumption by 15% reducing carbon emissions by an estimated 23M tonnes (source EPSRC).

The adoption of solid state lighting technology to reduce energy consumption and improve sustainability has driven the development of new measurement methods to adequately characterise commercial and domestic lighting. To allow international standards to produce a uniform definition of acceptable lighting levels, new techniques for measurement traceability have been developed.

To regulate the marketplace European and International standards have been produced to account for the difference of SSL sources to traditional incandescent luminaires. The quantification of energy efficiency, novel research to improve efficiency and aspects of the beneficial effects and potential hazard of light sources will be discussed.

15:10-16:10 General discussion / future directions

Additional information

Our sponsors:

Institute of Advanced Studies

The Institute of Advanced Studies at the University of Surrey hosts small-scale, scientific and scholarly meetings of leading academics from all over the world to discuss specialist topics away from the pressure of everyday work. The events are multidisciplinary, bringing together scholars from different disciplines to share alternative perspectives on common problems.

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IOP Institute of Physics Semiconductor Physics Group

The Institute of Physics is a leading scientific society. We are a charitable organisation with a worldwide membership of more than 50,000, working together to advance physics education, research and application. We engage with policymakers and the general public to develop awareness and understanding of the value of physics and, through IOP Publishing, we are world leaders in professional scientific communications. The Semiconductor Physics Group serves as a common forum for industrial and university researchers concerned with the physics, preparation and application of semiconducting materials and device structures, such as those described at this workshop.

www.iop.org/activity/groups/subject/sem/

lumie helping you to shine

Since 1991 Lumie has been researching and designing bright lights to treat seasonal affective disorder (SAD) and other conditions. Our first Bodyclock dawn simulator – an alarm that wakes you up with increasing levels of light – was the world's first wake-up light and brought light therapy into the mainstream. We also designed and developed Lumie Clear, a unique hand held device that uses combined blue and red light therapy to treat acne.

www.lumie.com

Additional information

<u>Glossary: </u>(a small selection of technical terms)

bandgap: energy gap in semiconductors (and insulators) in which no electronic states exist. Determines the emission wavelength of a light source made from that semiconductor.

circadian: related to biological processes that occur regularly at 24h intervals

c-plane: specific crystal plane in semiconductors, in Gallium nitride based materials it has an induced electric field – polar

> *semipolar*: another crystal direction with less of a field effect
>
> *a direction, 11-22*: other crystal directions

defects in semiconductors: deviations from perfect crystal structure caused by impurities (atoms of different material) leading to *threading dislocations* or *stacking faults*

epitaxial: process to make ("grow") semiconductor nanostructures

hypothalamus: small part of brain just above brainstem that is among other things controlling sleep and circadian rhythm

InGaN: Semiconductor material consisting of Indium Gallium and Nitride with a bandgap i.e. light emission in the visible, *III-nitrides*: other group III elements in combination with GaN

internal quantum efficiency: measure of the fundamental efficiency of an LED before considering output (external efficiency)

MQW: multi quantum well, series of very narrow (~nm) regions with lower bandgaps to their surroundings needed for efficient light generation

neurodegenerative diseases: conditions that effect the neurons in the brain (e.g. Parkinsons, Alzheimers)

opsin: light sensitive protein in the photoreceptor cells of retina, convert light into electrochemical signal

> *melanopsin*: a particular opsin that is involved in the non-visual response to light, i.e. circadian rhythm and pupillary light reflex
>
> *rhodopsin*: opsin (pigment protein) found in rod photoreceptors

optogenetics: to use light to control light sensitive neurons

photonic crystal: periodic structure (e.g. material with grid of holes) that creates photonic bandgap, i.e. certain wavelengths cannot propagate

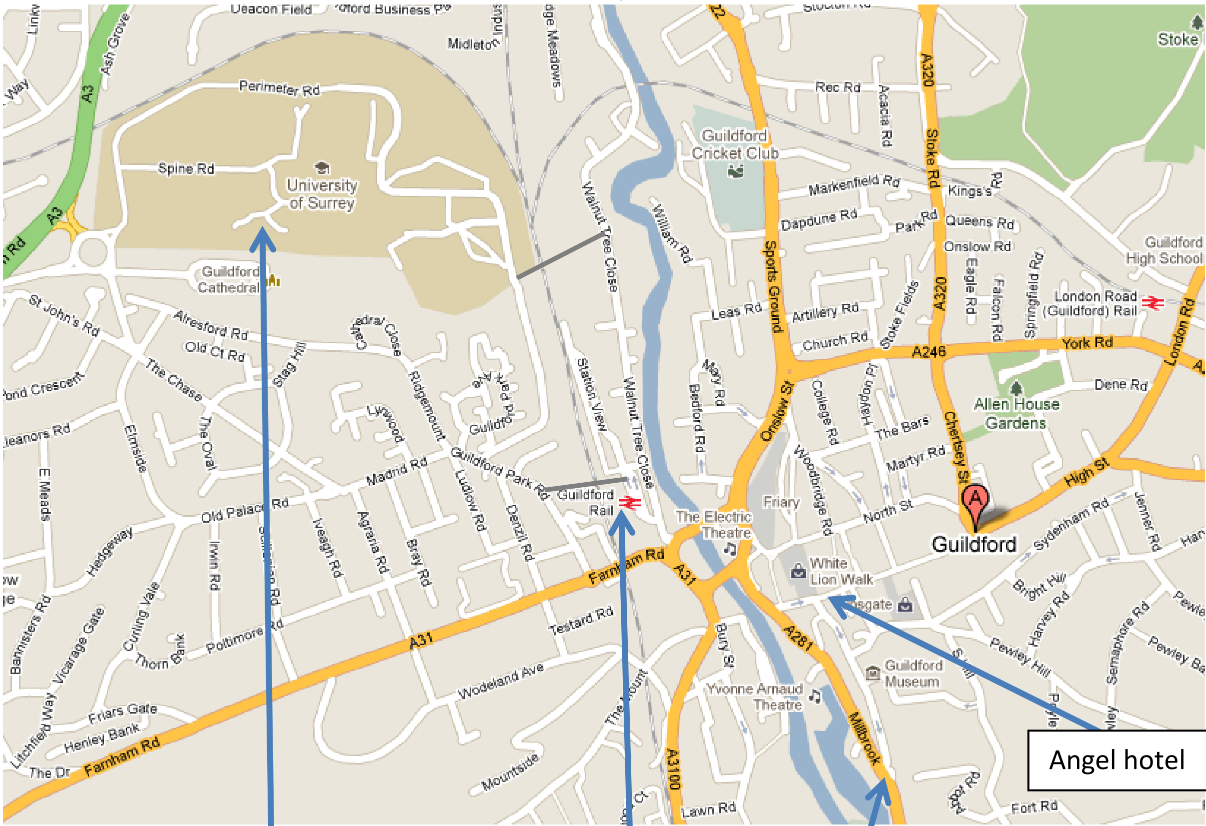
pupillary light reflex (PLR): resizing of pupil due to light

retinal ganglion cells: neurons near retina, receive information from photoreceptors, both visual and non-visual response

Additional information

Map of Guildford and the University

Travelodge



Angel hotel

Workshop venue: Treetops in Wates house, University of

Guildford main train station

Weyside Pub: Workshop dinner in the “Barn” on 21st September from 18:30 onwards.

Campus map

Car Park

Walkway towards town centre and station (main entrance).

Workshop venue: Treetops in Wates house, University of Surrey

Walkway from/to station (rear entrance).